Mobile Manipulation and Survey System for H-Canyon and other Applications across the DOE Complex

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ABSTRACT:

The University of Texas is leading a diverse consortium to develop and deliver a mobile manipulation and survey system capable of meeting the requirements necessary to properly inspect and survey the H-Canyon air ventilation tunnels at Savannah River Site.

H-Canyon began operations at the Savannah River Site in 1955 and is the only hardened nuclear chemical separations plant still in operation in the United States. The H-Canyon Air EXhaust (CAEX) tunnels connecting the facility to the sand filters must be periodically inspected, but the conditions are harsh: 30+ mph air flow, acid vapors, alpha contamination (millions dpm/100 cm^2), high beta and gamma dose (10 to 1,000 mRem/hr), uneven floor surfaces, obstacle debris and "muddy" paths, 30+ cm of standing water, and overhead obstacles (1m and 0.5m high air ducts). Since 2003, 5 crawlers have been deployed with various levels of success and in various sections of the over 300 meters of tunnels of H-Canyon. In 2015, the Recovery Crawler (RC) was deployed to either retrieve the 2014 Inspection Crawler (IC) or move it out of the inspection path. It was able to move the IC out of the inspection path and return home, but the IC (and its predecessors) is no longer operable. The RC was retrieved but cannot provide the necessary (or desired) inspection capabilities. After the mission, the SRS team concluded they require a system with
- the ability to be deployed through existing port (i.e. 30" diameter, high above the floor, and in windy conditions);
- a more robust method for traversing the numerous, unknown and ever-changing obstacles and water puddles. Mission risk must be reduced;
- the ability for the system to right itself if it does tip; and
- better methods to view behind hanging ducts, pipes and other obstacles.

Furthermore, there is a desire to
- develop a more comprehensive suite of sensors capable of providing data beyond simple video imaging including radiation survey data, collect soil/water samples, structural images via NDT techniques such as neutron radiography, and environmental data;
- collect SLAM data from LIDAR and other sensors used for navigation to develop better models of the CAEX tunnel;
- perform more comprehensive inspections including the collection of core samples and possibly NDT of the tunnel walls;
- integrate SLAM and radiation data for analysis and visualization; and
- perform all these activities in real-time.

A comprehensive list of the requirements was compiled and is included in the proposal. It is noted that a system that meets these requirements must address aspects of all 7 of the IRP areas of interest.

But even for the base requirements listed above, a developed system will require higher significantly higher costs than the customer prefers and more advanced technical capabilities than those used in past efforts. To address this need, the UT Austin is leading a diverse, uniquely qualified team to develop and deliver a mobile manipulation and survey system that meets the challenging requirements necessary to properly inspect and survey in the harsh conditions of the CAEX tunnel.

To complete these challenges, the team will develop a hybrid mobile platform capable of maneuvering using wheels, treads or articulated legs. The treaded legs can fold back into the platform providing a compact system that can be deployed given a 27" circular clearance. The platform will carry a manipulation and survey package. The manipulation platform is a proven industrial manipulator with a 1 meter reach and 5 kg payload that extends the system's inspection and survey capabilities via a set of interchangeable end-effectors. The delivered system will include a suite of high resolution cameras, radiation sensors and sampling capabilities to perform structural analysis of the tunnel. The option of a portable NDT system will also be explored.

It is recognized that any single large system may not be able to reach or inspect all areas within the tunnel. Thus, the system will be able to deploy smaller subsystem(s) adopted from previous efforts to inspect DOE storage tanks and piping which will be adopted for this purpose. Thus, the team will be able to provide a comprehensive solution for H Canyon tunnel inspection assembled from a combination of novel and proven technologies that will have applications beyond the targeted application including the inspection long-term storage facilities, tank inspection, and event response.

The team assembled for this project has already developed many of the hardware and software capabilities necessary to complete this mission. The proposal comprehensive documents these capabilities to identify the remaining technology gaps which are address in the research. The **University of Texas at Austin** has already developed and demonstrated a dual-arm mobile manipulation system for remote inspection of facilities at LANL as well as demonstrated the capability to use mobile systems to perform radiation surveys and sweep for alpha contamination using control paradigms ranging from true autonomy to tele-operation. Additionally UT Austin has demonstrated the capability to automate both x-ray cartography and neutron radiography. The **University of Florida** has extensive experience in radiation hardening, mobile platform design, a proven record developing and designing autonomous navigation capabilities for mobile systems. **Florida International University** provides a set of smaller subsystems which can be adopted and deployed as needed in the tunnel to ensure the inspection is comprehensive. These universities constitute the development team. To succeed, we have included an advisory team to ensure the system meets the challenging requirements and is properly verified and validated. **AREVA** has proven experience deploying hardware systems to perform similar tasks across the globe. **SRNL** provides guidance with the respect to the requirements and facilitate the successful delivery of the final system. All three universities have experience using the Robot Operating System (ROS) which ensures the software developed by each university is not only easy to integrate, but also available to support applications beyond H-Canyon.

The **final deliverable is a functional prototype delivered for evaluation at a DOE designated facility to perform inspection tasks in a fully representative CAEX tunnel environment** that includes a 30" access port, tunnel of accurate dimension and sufficient length. It must include a fully representative set of obstacles (ducts, debris, pooling water, etc.), and – if possible – be representative of harsher conditions including wind, presence of acid, radiation contamination. If this is not possible – and in either case – a final report on the radiation and contamination testing related to individual components and subsystems. To ensure the system is transferrable and the adopted and developed technologies are transferrable to other applications, the proposal includes a detailed date management plan as part of the management and collaboration structure that assures systems are properly documented and all relevant data, drawings, code, and operating documentation is properly archived.